Sustainable Supplier Evaluation practices across the Supply Chain[1]

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Abstract

In the last decade, academic research on sustainability has evolved rapidly in the supply chain literature, so there has been scant opportunity thus far for the research community to complete a global assessment of sustainable supplier evaluation activities. This paper seeks to address this need by exploring sustainable supplier evaluation practices and developing a multiple criteria decision-making (MCDM) model based on the combination of the triple bottom line (TBL) and the TOPSIS methodologies to help managers evaluate external providers all along the supply chain. In order to create a robust framework for sustainable supplier evaluation, two case studies were selected and compared. Both case studies were also useful to refine the framework and illustrate how to use it. Identifying best practices for integrating corporate social responsibility involves the evaluation of external providers' certification according to the ISO 9001, ISO 14001, ISO 50001 and ISO 45001 standards. Accepting the firm's code of conduct and monitoring it throughout the whole supply chain phases are relevant factors to be considered in order to ensure procurement sustainability. The proposed model can be used as a guideline to provide managers, practitioners and academics with a practical solution to resolve external provider evaluation decisions and determine the ranking order of preferred external providers in a more structured and consistent manner

Keywords

Supplier evaluation, decision-making, sustainable outsourcing, sustainable supply chain, CSR (Corporate Social Responsibility).

1. Introduction

There is a growing audience for sustainable supplier evaluation research, as the importance of analytical expertise, general management backgrounds, and deep knowledge in a particular purchasing category becomes widespread. The ISO 26000 standard released in 2010 provides guidance on understanding, implementing and continuously improving the social responsibility of organizations, which is understood as the impact of firms' actions on society and environment. ISO 26000 defines seven principles of social responsibility (ISO 26000, 2010):

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- Accountability: being answerable for decisions and activities and their impact on society, the economy and the environment.
- Transparency: being open about decisions and activities that have an impact on society and the environment.
- Ethical behavior: in accordance with accepted principles of right or good conduct.
- Respect for stakeholders' interests: respecting, considering and responding to the interests of stakeholders.
- Respect for the rule of law: mandatory.
- Respect for international norms of behavior.
- Respect for human rights.

How can firms evaluate their suppliers' effectiveness including sustainable criteria? The interest of researchers and practitioners about the literature favoring "buy" decisions and supplier evaluation has increased in the last decades. Supply selection and evaluation decisions have been addressed from multiple viewpoints. Due to the importance of sustainability in the supply chain systems, there is a need to update the sustainable sourcing literature as part of the supplier development process to help and guide practitioners to

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evaluate sustainability criteria within the supply chain. The purpose of this study is to solve this need by designing a sustainable external provider evaluation framework by further developing the triple bottom line (TBL) concept, integrating subcategories, and presenting a multi-criteria approach. The rest of the paper is structured as follows. First, Section 2 reviews the literature on supplier evaluation processes with focus on sustainable supply chain practices and develops the supplier evaluation framework. Second, the firms involved in the multiple case study are presented in Section 3. Then, Section 4 described the best practices for the implementation of the proposed framework integrated in the model (pairwise comparison and decision matrix) for real case studies. Findings from the multiple case study and the validation of the framework are explained in Section 5. Finally, discussions and conclusions are outlined in Section 6.

2. Literature review

2.1. Literature review on the supplier evaluation process

Chen, Lin and Huang (2006) presented a fuzzy decision-making approach to deal with the supplier selection and evaluation problem in supply chain systems. They proposed the TOPSIS concept as a hierarchy multiple criteria decision-making (MCDM) model to solve the external provider selection problem. Sevkli et al. (2007) implemented the data envelopment analytic hierarchy process (DEAHP) methodology for supplier selection and evaluation in a case study at Beko in Turkey. They highlighted the consistency of this hybrid method as compared to the AHP methodology alone. However, they did not take into account the demands of various stakeholders to comply with environmental legislations and social responsibilities. Whereas Gencer and Gürpinar (2007) developed a model based on the analytic network process (ANP) to systematize supplier selection and evaluation practices, Tsai, Huang and Wang (2008) combined the ANP and TOPSIS concepts for evaluating the performance of property-liability firms. TOPSIS is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon (1981), with further developments by Yoon (1987) and Hwang, Lai and Liu (1993). TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution (Assari, Mahesh and Assari, 2012). Furthermore, Boran et al. (2009) proposed an intuitionistic fuzzy set for finding the best option of all the feasible alternatives.

In contrast, Öztürk and Özçelik (2014) examined how to identify the best supplier by means of sustainability principles for supplier selection and evaluation operations. They presented a multi-criteria analysis and solution approach based on the TOPSIS method and including the sustainable criteria defined in the Triple Bottom Line (TBL) method. Also, the TBL (profit, people and planet) approach was chosen by Sarkis and Dhavale (2015) to create a Bayesian framework for evaluating external providers. TBL is a method for measuring sustainability performance developed by Elkington (1994) and perfected by Jackson, Boswell and Davis (2011). TBL is an approach for management and performance evaluation that emphasizes the importance of economic, environmental, and social performance. Although Öztürk and Özçelik's (2014) approach employed a well-known and useful methodology like the TOPSIS concept, they failed to consider strategic, resource and quality conformance criteria within their approach. Furthermore, Chaharsooghi and Ashrafi (2014) proposed a sustainable supplier selection and evaluation model combining an improved version of the TBL methodology with the neofuzzy TOPSIS methodology. Hence, we identified the employment of the TBL and TOPSIS methodologies to address sustainable supplier evaluation decisions.

2.2. Literature approach on the supplier evaluation framework

As has been done in the past by other researchers we have summarized the most relevant external provider evaluation criteria into main clusters. In addition to the theories categorized by Dibbern et al. (2004), we have identified theories and insights concerning sustainable procurement, combinations of the transaction cost economics (TCE) and resource-based view (RBV) theories and supplier evaluation frameworks. In essence, the TBL theory and methodology for the measurement of sustainability performance was taken into account. As observed from the literature, this theory has been employed by both academics and industrialists to evaluate the grade of sustainability on external providers' selection and evaluation practices (Elkington, 1994; Öztürk and Özçelik, 2014).

After the interview with EcoVadis, a renowned service provider for supplier sustainability ratings, we realized that the TBL concept is also employed in the industry for assessing the sustainability risks involved (EcoVadis, 2018). Due to the increased relevance of sustainable procurement in the last decade, we have adapted the hierarchical structure of sustainable supplier evaluation's concept of Öztürk and Özçelik (2014) of three streams, namely: (1) economic value; (2) environmental position; and (3) social responsibility. Every stream or main cluster is subcategorized into the main TOP4 sub-criteria for the corresponding evaluation. The structure of the framework with the definition of these main clusters are implemented into the pairwise comparison sheet.

The first stream (economic) analyzes external provider evaluation from an economic perspective, which is broken down into four subcategories, mainly: (1) costs; (2) quality; (3) lead time and on-time delivery; and (4) technological capability.

(1) What should firms buy for maximizing profits while keeping a low risk for opportunism? This subcategory approaches sustainable procurement taking into account opportunism from a cost perspective and a risk mindset, based mainly on the TCE theory (Coase 1937; Williamson 1975, 1981, 1985). The main theoretical argument of this theory is concerned with the fact the conditions of the transaction would lead to its internal or external governance. It has two fundamental behavioral assumptions: (1) bounded rationality (Simon 1957) and (2) opportunism. This risk of opportunism is a factor addressed in the game (Fudenberg and Tirole, 1990) and agency (Eisenhardt, 1989) theories, intended to safeguard firms from possible risks. When applied to the external provider evaluation process, it posits that firms need to consider second source alternatives for ensuring an emergency plan B, thus gaining a better negotiation position with providers. The potential for opportunism evaluation considers the following criteria: (1) quality defects; (2) delivery delays; (3) costs increase; (4) skills appropriation; and (5) complexity relationship / conflict resolution. The subcategory definition was provided in order to simplify the terminology for practitioners. The conflict resolution criterion, among others, was also supported by Chen, Lin and Huang (2006) in their supplier selection approach.

(2) The second subcategory addresses external provider evaluation from a quality conformance perspective. As the importance of quality has much increased in the last years, we have defined a mainly quality-focused cluster based on other supplier evaluation approaches (Chen, Lin and Huang, 2006). Quality has received so much attention that there are quality certifications for firms and practitioners. In recent years, firms' processes are usually controlled by quality managers and documented in a quality management handbook (QMH). We considered the following criteria within this subcategory: (1) QM assessment; (2) audit result; (3) certification; (4) willingness for contractual agreements (CA); (5) supply chain monitoring; (6) assessment of whether a completed product/service, or part of it, fits the supply chain; and (7) traceability.

(3) Lead time and on-time delivery is a strategic criterion and key performance indicator (KPI) monitored by many firms, as a delivery delay by an external provider can cause a manufacturing planning delay followed by a customer order delay. One of a firm's targets is to deliver customer orders on time.

(4) The fourth subcategory examines dichotomous external provider evaluation from a resource viewpoint (Barney, 1991; Penrose, 1959; Pfeffer and Salancik, 1978; Thompson, 1967). First, the resource perspective plays an important role, especially in the RBV (Barney, 1991) and the resource dependency theory (Pfeffer and Salancik, 1978). Chen, Lin and Huang (2006) introduced the main technological capability criteria to be considered in supplier evaluation frameworks. Thus, after introducing the main findings from the abovementioned literature, we consider the following criteria within this subcategory: (1) process capability available; (2) skills and know-how available; (3) process maturity; (4) assets available; (5) support systems; and (6) technological and manufacturing capability. The subcategory definition was provided in order to simplify the terminology for practitioners.

The second stream (environmental) addresses the dichotomous external provider evaluation decision from an environmental viewpoint which is split into four subcategories, mainly: (1) pollution control; (2) resource consumption (ISO 50001 - Energy Management); (3) green product and eco-design (REACH/RoHS and conflict minerals reporting template (CMRT)); and (4) environmental management system (ISO 14001). Using energy efficiently helps organizations save money and resources and tackle climate change. According to Öztürk and Özçelik (2014), firms started to analyze their supply chains to enhance their overall sustainable supply chain management (SSCM) profile and meet the demands of stakeholders and customers to comply with environmental legislation. SSCM refers to the integration of environmental and social issues into supply chain management (SCM) in order to improve firms' environmental, social and economic performance (Gimenez, Sierra and Rodon, 2012; Öztürk and Özçelik, 2014). The sustainable supplier evaluation process is a central concept of sustainable supply chain management.

The third stream (social) delves into external provider evaluation from a social viewpoint. We break down the social stream into: (1) health and safety practices (BS OHSAS 18001/ISO 45001 - Occupational Health & Safety); (2) social responsibility; (3) education infrastructure; and (4) employment practices. The second and third streams deal with external provider evaluation from an environmental and social responsibility perspective taking into account suppliers' CSR (Corporate Social Responsibility) score and suppliers' code of conduct (CoC). Over the last few years, following the release of the ISO 26000 guidelines, more attention has been paid to sustainable procurement, and firms have started to consider environmental and social criteria, besides economic ones, to evaluate their external providers. Supply chain management sustainability has been explored in recent years by some researchers who identify the need to develop a framework for the implementation of social responsibility in the external provider evaluation process (Chaharsooghi and Ashrafi, 2014).

In contrast to the past reviewed approaches, our proposed approach can be adapted to specific firm's decision makers hierarchy, by assessing the relevance of the decision makers involved.

On the other hand, supplier requirements in terms of economic, environmental and social differ from specific manufacturing activities and material groups. Thus, the defined ideal punctuation can be set and adapted into the decision matrix for single supplier evaluations.

3. Data collection methods

In order to create a robust framework and examine the practicality and effectiveness of the proposed sustainable supplier evaluation approach, two case studies were selected and compared. The main criterion for the selection of the cases was the convenience of one of the authors with both firms. One supplier is located in Europe and the other is overseas, in China. The firm A is the tier 1 and the firm B is the tier 2 of an end-German-customer. Both suppliers were visited and interviewed using the proposed framework. Several issues required to be addressed. First, a better understanding of how sustainable supplier evaluations are understood in China and Europe is required. Second, a better understanding of the lessons learned and improvement potentials collected from the interviews with decision makers from both firms had to be analyzed and prioritized. Third, a clear understanding of the interrelation between the firm, third parties and the triggers, factors, intercultural communication and possible outcomes of supplier evaluation approaches should be identified. The interviews, their design, the analysis of the transcripts and how the findings were incorporated into the framework are described here. An analysis of the recent external provider evaluation literature was performed and served as the basis for preparing and designing the interviews. Semi-structured interviews with middle-level managers from both firms were conducted. An interview questionnaire with a preliminary framework was designed based on the literature and served as an interview guide. Interview sessions took slots of over one hour and mainly covered the following topics:

- areas related to external provider evaluation
- criteria to be considered during sustainable external provider evaluation
- functions involved in the sustainable external provider evaluation process
- strengths and weaknesses of current and past decisions
- lessons learned and suggestions from current and past decisions
- stages taken into account during the external provider evaluation process

3.1. Case Study: Firm A

To undertake the first case study, we collected information on how previous external provider evaluation decisions had been approached. The information was obtained from an experienced printed circuit board assembly (PCBA) and electronics manufacturing services (EMS) provider. The firm, based in Slovakia and exporting mainly to Germany and the European market, has been active since 1995. It has approximately 200 employees and a €11 million revenue (key figures from 2017). The firm is ISO 9001 (Manufacturing), ISO/TS 16949 (Automotive), ISO 18001 (Occupational Health and Safety) and ISO 14001 (Environment) certified and also complies with RoHS, REACH and conflict minerals directives. Additionally, the firm has an intern code of conduct (CoC) which contains the main social criteria defined in ISO 26000. The scope of the firm management system complies with the ISO 80079-34 and ISO 13485 standards. Yearly environmental and social targets are defined, documented and monitored. The firm allegedly has a green energy certificate from Slovenské elektrárne, which is the largest power generating company and the biggest investor in Slovakia. Firm facility environmental control system is ISO 14001-certified.

3.2. Case Study: Firm B

The second case study was based on the information on previous external provider evaluation decisions obtained from a leading manufacturer of printed circuit boards (PCB). The firm is a global player based in Shenzhen, China with three manufacturing facilities, eight sales tech support offices and 80 sales representatives. The firm has approximately 2,100 employees and a $152 million revenue (key figures from 2017), with a revenue forecast of $198 million for 2018. The case study was undertaken in order to document the external provider evaluation process for previous and ongoing decisions. The firm is ISO 9001 (Manufacturing), ISO/TS 16949 (Automotive), ISO 13485 (Medical) and ISO 14001 (Environment) certified and also complies with the U.S. Dodd-Frank Act for conflict minerals. Additionally, the firm has an intern and external provider code of conduct (CoC) which contains the main social criteria defined in ISO 26000. The visited headquarter in China complies with RoHS, REACH and PFOS directives and is ISO/TS 14067 (Product Carbon Footprint) certified.

4. Best practices for the implementation of the framework

In order to explain the practical implementation of the framework into the model (pairwise comparison and decision matrix), the interdependencies between elements and the pairwise comparison and to collect best practices for sustainable supplier evaluation, we put into the practice the model using a multiple case study. When choosing decision makers (DM) for the interviews at the multiple case study, we selected those decision makers within the procurement

process of firm A and B who were most willing to explain the decisions made at their workplace. Those decision makers who have a business relationship with one of the authors, who is involved in the supplier evaluation process, are categorized into three levels: (DM1) who are represented by managers and strategic purchasers; (DM2) Research & Development, industrial engineers and specialists; and (DM3) for quality assurance and quality representatives. The weight of decision maker levels is set as follows: DM1 is 0,406; DM2 is 0,238; and DM3 is 0,356 so that the total of the weighting is 1 (Boran et al., 2009).

Compared to the previous alternative approaches reviewed, one of the main novelty of our approach is the standardization of fix decision makers weights for all supplier evaluation decisions according to their function at the firm defined in the firm's organigram. This contribution was preferred by practitioners in order to simplify the tool. Decision makers of both firms were asked to respond to a series of pairwise comparisons where two criteria elements at a time were compared in terms of how they contribute to their corresponding upper level criterion.

Figure 1 Pairwise comparison Firm B
Source: Own source.

Determine the weights of criteria

Pairwise comparison

more important than

			Economic	Environmental	Social	Total	Weight (%)-Factor
1		Economic		1,5	1	2,5	8,0
11	TOP1	Costs (Eco1)		2	1		
12	TOP2	Quality (Eco2)		1	2		
13	TOP3	Lead time and on time delivery (Eco3)		1	0		
14	TOP4	Technology capability (Eco4)		2	1		
2		Environmental	1		2	3,0	10,0
16	TOP1	Pollution control (Env1)	1		2		
17	TOP2	Resource consumption (Env2)	1		2		
18	TOP3	Green product and eco-design (Env3)	1		2		
19	TOP4	Environmental management system (Env4)	1		2		
3		Social	1	2		3,0	10,0
21	TOP1	Health and safety practices (Soc1)	1	2			
22	TOP2	Social responsibility (Soc2)	1	2			
23	TOP3	Education infrastructure (Soc3)	1	2			
24	TOP4	Employment practices (Soc4)	1	2			

The consistency of each pairwise comparison was also checked in this step. The relative importance values are determined on a scale of 0 to 2, where a score of 0 represents less importance than the other criterion, a score of 1 indicates equal importance between the two elements, and a score of 2 indicates the maximum importance of one element (row component in the matrix) compared to the other one (column component in the matrix) following Figure 1 (Fim B). The weightings of each criterion are then determined and adapted in the pairwise comparison. For example, the assessment by the pairwise comparison between Quality (Eco2) and environmental is 1, which means that Quality is equally important than environmental. Economic cluster is weighted with 8% calculated from the division between 2,5 and the maximum value from the "Total" column, multiplied by ten (weight(%) factor for economic is INT((2,5/(MAX(2,5;3;3)))*10)=8). On the other case study, three decision makers from the management, engineering and production areas assessed the scores determined on a scale of 0 to 2 as described above, but separately. For instance, the social cluster of Firm A is weighted with 9, 10 and 8 by DM1, DM2 and DM3 respectively. These weighting factors results are added into the social cluster's weighting factor field of the decision matrix of the Firm A. Results of the pairwise comparison are illustrated in Figure 2.

Figure 2 Pairwise comparison of Firm A
Source: Case study - Firm A.

DM1

Pairwise comparison — Determine the weights of criteria — more important than

		Economic	Environmental	Social	Total	Weight (%)-Factor
1	Economic		1,3	1,5	2,8	8,0
TOP1	Costs (Eco1)		1	1		
TOP2	Quality (Eco2)		1	2		
TOP3	Lead time and on time delivery (Eco3)		1	2		
TOP4	Technology capability (Eco4)		2	1		
2	Environmental	1,5		1,8	3,3	10,0
TOP1	Pollution control (Env1)	2		2		
TOP2	Resource consumption (Env2)	2		2		
TOP3	Green product and eco-design (Env3)	1		1		
TOP4	Environmental management system (Env4)	1		2		
3	Social	1	2		3,0	9,0
TOP1	Health and safety practices (Soc1)	1	2			
TOP2	Social responsibility (Soc2)	1	2			
TOP3	Education infrastructure (Soc3)	1	2			
TOP4	Employment practices (Soc4)	1	2			

DM2

Pairwise comparison — Determine the weights of criteria — more important than

		Economic	Environmental	Social	Total	Weight (%)-Factor
1	Economic		1,8	1,3	3,0	10,0
TOP1	Costs (Eco1)		2	1		
TOP2	Quality (Eco2)		1	1		
TOP3	Lead time and on time delivery (Eco3)		2	2		
TOP4	Technology capability (Eco4)		2	1		
2	Environmental	1,3		1	2,3	7,0
TOP1	Pollution control (Env1)	1		1		
TOP2	Resource consumption (Env2)	2		1		
TOP3	Green product and eco-design (Env3)	1		1		
TOP4	Environmental management system (Env4)	1		1		
3	Social	1	2		3,0	10,0
TOP1	Health and safety practices (Soc1)	1	2			
TOP2	Social responsibility (Soc2)	1	2			
TOP3	Education infrastructure (Soc3)	1	2			
TOP4	Employment practices (Soc4)	1	2			

DM3

Pairwise comparison — Determine the weights of criteria — more important than

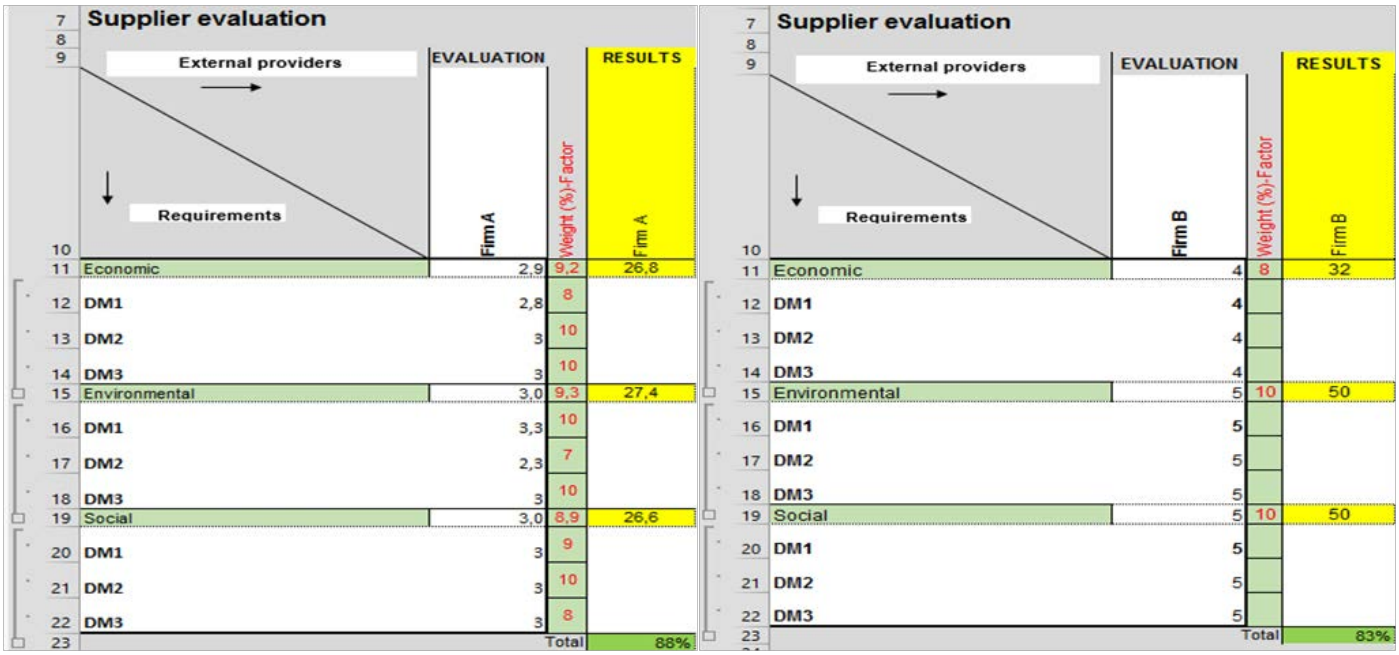
		Economic	Environmental	Social	Total	Weight (%)-Factor
1	Economic		1,5	1,5	3,0	10,0
TOP1	Costs (Eco1)		1	1		
TOP2	Quality (Eco2)		2	2		
TOP3	Lead time and on time delivery (Eco3)		2	2		
TOP4	Technology capability (Eco4)		1	1		
2	Environmental	1,5		1,5	3,0	10,0
TOP1	Pollution control (Env1)	1		1		
TOP2	Resource consumption (Env2)	2		1		
TOP3	Green product and eco-design (Env3)	1		2		
TOP4	Environmental management system (Env4)	2		2		
3	Social	1	1,5		2,5	8,0
TOP1	Health and safety practices (Soc1)	1	1			
TOP2	Social responsibility (Soc2)	1	1			
TOP3	Education infrastructure (Soc3)	1	2			
TOP4	Employment practices (Soc4)	1	2			

The supermatrix is built using the underlying logic of TOPSIS, which involves defining the ideal solution and the negative ideal solution. The ideal solution is the solution that maximizes the benefit criteria and minimizes the cost criteria; whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. The optimal alternative is the one which is closest to the ideal solution and farthest from the negative ideal solution. The ranking of alternatives in TOPSIS is based on "the relative similarity to the ideal solution", which avoids the situation of having the same similarity to both the ideal and the negative ideal solution (Deng, Yeh and Willis, 2000). To obtain global priorities in a system with interdependent influences, the local priority vectors are entered in the appropriate columns of a matrix, known as a supermatrix. As a result, a supermatrix is actually a partitioned matrix, where each matrix segment represents a relationship between two nodes (components or clusters) in a system.

The framework detailed above provides a comprehensive account of relevant areas, factors, possible triggers and outcomes to be considered in supplier evaluation decisions. However, it is necessary to weight and rate these areas and factors for practical cases. In addition to the one-page graphical illustration, a tool with a decision matrix was developed based on the guidelines of the pairwise comparison technique (Thurstone, 1927) and the technique for order preference by similarity to ideal solution (TOPSIS) method. The pairwise comparison technique is widely employed to handle subjective and objective judgments in multi-criteria decision-making, especially as a method to determine the weighting of criteria (Kou, Ergu and Shang, 2014). The TOPSIS method has been analyzed using multi-criteria models for complex decisions and multiple attribute models for the most preferable choice.

Based on the supermatrix, each condition is evaluated on a scale of 1 to 5, where a score of 1 means that the condition does not meet the requirements, a score of 2 indicates that the requirements are only partly met, a score of 3 indicates that the requirements are almost completely fulfilled, a score of 4 means that the requirements are fully met and a score of 5 indicates that the condition reaches a level of excellence. The weightings of each criterion are then determined and adapted in the supermatrix. A better understanding of the framework's implementation into the supermatrix is illustrated from a multiple case study in Figure 3 by comparing the assessment of both case studies. Whereas the Firm B assessed the weighting of the main cluster using the pairwise comparison tool together in a consensual workshop, decision makers from the Firm A assessed the weighting of criteria individually. Admittedly, the environmental cluster is the most relevant for both firms which is weighted with a factor of 9,3 and 10 for Firm A (PCBA) and Firm B (PCB) respectively. While the ideal expected punctuation set at the firm for suppliers belonging to the PCB material group's category is defined to five for the three main clusters, the PCBA's ideal punctuation is set to 3, 3.1 and 3.3 for the economic, environmental and social clusters respectively. Thus, Firm A and Firm B are evaluated with 88% and 83% degree of completion respectively from a maximum punctuation of 100%.

Figure 3 Decision matrix assessment: Firm A vs. Firm B
Source: Multiple case study: Firm A and B.



Supplier evaluation				
External providers / Requirements	EVALUATION Firm A	Weight (%)-Factor	RESULTS Firm A	
Economic	2,9	9,2	26,8	
DM1	2,8	8		
DM2	3	10		
DM3	3	10		
Environmental	3,0	9,3	27,4	
DM1	3,3	10		
DM2	2,3	7		
DM3	3	10		
Social	3,0	8,9	26,6	
DM1	3	9		
DM2	3	10		
DM3	3	8		
Total			88%	

Supplier evaluation				
External providers / Requirements	EVALUATION Firm B	Weight (%)-Factor	RESULTS Firm B	
Economic	4	8	32	
DM1	4			
DM2	4			
DM3	4			
Environmental	5	10	50	
DM1	5			
DM2	5			
DM3	5			
Social	5	10	50	
DM1	5			
DM2	5			
DM3	5			
Total			83%	

A supermatrix can be employed to determine the effects of interdependence between the elements of the system. It is a partitioned matrix, where the weighted values are obtained from the pairwise comparison matrix. The supermatrix is calculated according to the procedure defined in the research by Temuçin et al. (2013), comprising the following steps:

Step A. Creating decision (A) and weighting (W) matrices:

At the beginning, the decision matrix, which consists of three components, has to be determined. These components are alternatives defined by a1, a2, ..., ai, am; criteria defined by c1, c2, ..., cj, cn; and performance values defined by aij (i = 1, 2, ..., m) (j = 1, 2, ..., n). Additionally, the weighting values for each criterion, w1, w2, …, wj, wn, are taken from the previous pairwise matrix result.

Step B. Creating the normalized decision matrix (X). The normalized decision matrix can be created according to Eq. (1) to make the data dimensionless.

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{ij}^2}} \quad (1)$$

Step C. Creating the weighted normalized decision matrix. The weighted normalized decision matrix can be created according to Eq. (2).

$$Y_{ij} = Y_{ij} \cdot W_j \quad (2)$$

Step D. Determining positive and negative ideal solutions considering the three main clusters and the rating scale (from 0 to 5). Positive and negative ideal solutions can be determined with Eqs. (3) and (4).

$$P_j^+ (\max P_{ij} ; c_1 - c_6) \quad (3)$$

$$P_j^- (\min P_{ij} ; c_1 - c_6) \quad (4)$$

Step E. Calculating separation measures. The positive and negative ideal separation measures, S_i^* and S_i^- respectively, can be calculated with Eqs. (5) and (6) as proposed by Temuçin et al. (2013).

$$S_i^* = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^*)^2} \quad (5)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_j^-)^2} \quad (6)$$

Step F. Calculating the relative closeness to the ideal solution. The relative closeness to the ideal solution, Ci*, for each alternative can be calculated according to Eq. (7).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (7)$$

where $0 \leq Ci^* \leq 1$ and i = (1,2,3,...,m).

Step G. Ranking alternatives in preference order. Finally, the alternative with the highest Ci* represents the best choice. External providers from the same material group can

be ranked with the supermatrix. In this step the decision and the alternatives are determined. The alternatives are selected from the successful ones in their field, Ci* C_1>C_2>C_3>C_4>C_5. The details of the scenarios are presented and second source options should be evaluated and, if appropriate, a multiple source strategy addressed according to the results. Results with a score within 100%-80% are highly recommended; those with a score within 80%-60% are recommended; those with a score within 60%-40% are recommended but involve some risk; for those with a score within 40%-20% the assessment status is recommended with high risk; and results with a score lower than 20% are not recommended.

5. Findings from the multiple case study

Any organization assessing a decision should critically examine and state what it wants to achieve through outsourcing. Both case studies were carried out using evidences from multiple sources, such as non-disclosure agreements (NDA), confidential disclosure agreements (CDA), supplier self-disclosure reports, supplier evaluation assessments, quality assurance agreements (QAA), supplier audit reports, delivery contracts, final reports and project plans, with a view to validity and reliability (Yin, 1994). Both case studies were also useful to refine the framework and illustrate how to use this framework.

The framework aims to provide a graphical representation of why and how supplier evaluation decisions are made. The framework is designed according to the three research streams (1) economic; (2) environmental; and (3) social; identified in the literature and confirmed through the findings analyzed in the case studies. A number of factors were suggested and incorporated into the framework as subcriteria.

External forces on which a firm's influence is minimal usually activate triggers and factors for the supplier evaluation analysis. For instance, the availability of a high number of qualified and expert external providers can allow the firm to focus on its core competence activities and outsource non-core activities. Thus, the firm can take advantage of external providers' expertise and a contractual cost reduction thanks to the economy of scale. In contrast to the existing supplier evaluation processes, our framework provides a practical and target-oriented overview where decision makers can evaluate external providers categorizing them into different material groups. This framework also appears to meet Miles and Huberman's (1984) requirements for building a comprehensive framework. Interestingly, the framework provides a big picture for academics and practitioners to locate the supplier evaluation process as part of strategic procurement activities. The supplier evaluation process should be documented and decision makers trained regularly in order to ensure the efficiency of the process.

5.1. An illustration of the framework using a case study

This section shows how this framework and its content are in line with the considerations of the multiple case study discussed. The triggers, the external elements which activate the triggers, the areas and factors and the final outcome in each case are discussed in this section. We will now illustrate the framework with the results of both supplier evaluation processes.

Firm and environment

The sustainable supplier evaluation process was related to the manufacturing of PCBs by Firm B and the PCB assembly involving electronic planar transformers by Firm A. Interestingly, Firm B sources PCBs to Firm A and both firms are an example of a successful overseas relationship within the supply chain.

Triggers

From the analysis of the case, it was clear that the main trigger for the supplier evaluation process was the new product introduction and the need to process the project in the required time. The current high demand of electronic manufacturing parts in the global market and the allocation of parts by suppliers makes difficult to find electronic manufacturing services (EMS) providers with enough resources, skills and expertise to accept this order. On the other hand, the Chinese firm has prototyping and customer support in Europe to closely support its customers and intermediate with the managers and the production in China. As a result of this, a multidisciplinary team was set up to conduct the supplier evaluation analysis.

Considerations for the sustainable supplier evaluation process

Economic considerations. These parts assessed for Firm A provide a clear competitive advantage and have a relatively high strategic value to the end customer because of their technical differentiation against competitors. This was a relevant factor, together with the close partnership involved, supplier profitability, multiple sourcing strategy, and demand flexibility. Whereas the lack of available contract manufacturers in the market with advanced technology and expertise in similar industries is currently an issue, the Slovakia-based firm has available resources to process and deliver customer projects within the expected time. Special test adapters and tooling would be required to perform the in-circuit and functional tests at the supplier's site. On the other hand, the Firm B is extending one of its PCB manufacturing sites in China so that its capacity will be increased and new customer orders can be accepted. The need to deliver this new product to the firm's end customers on time is a clear advantage for the firm against its competitors. In order to conduct an in-depth

supplier evaluation, an on-site supplier audit was performed by both suppliers on 13 March and 15 June 2018 in Slovakia and China respectively. Due to the special certification and technical requirements of the parts, a support system and team would be required.

Contract cost reduction was a relevant criterion, but a high delivery performance was fundamental for the assessment. The China-based firm obtained a high score in the assessment of its technology and manufacturing processes; moreover, its cost advantage and high resource position would help the firm complete the project within the expected time. The Slovakian supplier got a higher sustainability rating, which was consistent with both suppliers' certification and the on-site audit. Defining key performance indicators to monitor the process is essential to evaluate the outcome decision. Contract cost reduction indicators, delivery and quality performance figures and asset utilization were taken into account.

The level of quality, the delivery performance and the flexibility of both firms to deliver the project within the required time are excellent. Information asymmetry is a significant issue for both firms, as this research is based on a project where the final product is delivered to a German customer.

Other factors considered included the risk for an increase in quality defects, purchasing costs, delivery delays and a complex relationship with both external providers. Additionally, monitoring and auditing costs would be required to support the external provider until the process had reached maturity and stability at its site. A key selling point for both suppliers is that, in both firms, their customer support service is located in Germany, close to the end customer. After undertaking an audit on both sites, we verified that both firms are ISO 9001 and ISO/TS 16949 certified. Besides, the Chinese firm was ISO 13485 certified (requirements for manufacturers of medical devices). The Slovakian firm was more willing to enter into contractual agreements than the Chinese one, but the Chinese supplier provided a more reliable supply chain monitoring plan. The investment in technological assets by both suppliers improves the final product and decrease failures and errors in the supply chain.

Environmental considerations. Both external providers have a valid and certified environmental management system which complies with the ISO 14001 requirements. The aim of the end customer is to select a supplier with a high resource position, high profitability, high CSR reputation and low potential for opportunism, with a preference for centrally arranging the completed processes/services and having qualitative proof for certification bodies. The conflict minerals reporting template (CRMT) report, which is internationally standardized, is required as proof of conformity in connection with conflict minerals. One practical example of a CMRT report from CFSI is illustrated in Figure 4. Firm A has established a conflict mineral sourcing policy and its suppliers are required to be DRC conflict-free. "DRC Conflict-Free" is defined to mean products that do not contain conflict minerals or their derivatives determined to be directly or indirectly financing or benefiting armed groups in the Democratic Republic of Congo (DRC) or adjoining country (Sudan, Uganda, Rwanda, Burundi, United Republic of Tanzania, Zambia, Angola, Congo, Central African Republic). The firm is committed to support and subscribe to the use of DRC Conflict-Free Minerals which include gold (Au), tantalum (Ta), tungsten (W) and tin (Sn).Conflict minerals declaration statements are collected and corrective actions are assessed if appropriate. Due diligence information received is reviewed. This declaration sheet of Firm A is intended to identify smelters and confirm if any 3TG, like tantalum, tin and tungsten, is intentionally added or used in the products or in the production process. An example of the declaration sheet of Firm A is as follows:

1 Is any 3TG intentionally added or used in the products or in the production process?

Tin: HAL and chemical tin for PCB, solder paste, tin, wire tin - Pb, Pb-Free, electro-components

Gold: PCB pads

2 Does any 3TG remain in the product?

Tantalum and tungsten: no

Tin and gold: yes

3 Do any of the smelters in your supply chain source the 3TG from the covered countries?

Tin: yes

Gold: unknown

4 What percentage of relevant suppliers has provided a response to your supply chain survey?

Tin: greater than 75%

Gold: none

Figure 4 Conflict minerals reporting template (CMRT) CFSI
Source: Case study - Firm A.

Option A: If you know the Smelter Identification Number, input the number in Column A (columns B, C, E, F, G, I and J will auto-populate); D will grey out.

Smelter Identification Number Input Column	Metal (*)	Smelter Look-up (*)	Smelter Name (1)	Smelter Country (*)	Smelter Identification Number		Smelter Street	Smelter City
CID001182	Tin	Minsur	Minsur	PERU	CID001182	CFSI		Paracas
CID001482	Tin	PT Timah (Persero) Tbk Mentok	PT Timah (Persero) Tbk Mentok	INDONESIA	CID001482	CFSI		Mentok
CID002158	Tin	Yunnan Chengfeng Non-ferrous Metals Co., Ltd.	Yunnan Chengfeng Non-ferrous Met	CHINA	CID002158	CFSI		Gejiu
CID000468	Tin	Fenix Metals	Fenix Metals	POLAND	CID000468	CFSI		Chmielów
CID002455	Tin	CV Venus Inti Perkasa	CV Venus Inti Perkasa	INDONESIA	CID002455	CFSI		Pangkal Pinang
CID001477	Tin	PT Timah (Persero) Tbk Kundur	PT Timah (Persero) Tbk Kundur	INDONESIA	CID001477	CFSI		Kundur
CID000538	Tin	Gejiu Non-Ferrous Metal Processing Co., Ltd.	Gejiu Non-Ferrous Metal Processing	CHINA	CID000538	CFSI		Geiju

Social considerations. As part of the sustainable supplier evaluation, we evaluated both providers in terms of social, ethical and sustainable supply chain aspects. Both suppliers have established an internal code of conduct (CoC). Whereas the Chinese firm has a specific CoC for suppliers and the Slovakian firm does not, the work conditions in China lag far behind those in Europe. After the interview with some employees at the Chinese firm, we realized that they work 12-hour shifts and, when they start working, they have five holidays per year, which increase to ten holidays after ten years of employment at the firm. On the other hand, the firm offers employees dormitories close to the firm without charging extra costs for living, only costs for electricity, etc. This social benefit, the sports activities available and a canteen in the firm are very welcome by employees. Admittedly, many Chinese firms, like Firm B, were in the past ruled by the government, and this influence is still intrinsically seen in the firm. While the Slovakian firm has received an OHSAS 18001 - Occupational Health & Safety certification, Firm B does not have such a certification. Neither of these firms meets the CSR evaluation criterion, but the Slovakian firm has a quality management system (QMS) which takes into account yearly social targets. Hence, this crucial criterion is the most relevant one in the supplier evaluation.

Hereafter, the weighting of the defined clusters (economic, environmental and social) in the assessment by Firm A was evaluated by three decision makers from the management, engineering and production areas as an example for the operationalization of the framework.

The weightings of each criterion are then determined and adapted in the pairwise comparison.

Next, the normalized decision matrix for the three clusters was constructed using Eq. (1). Then, the weighted normalized decision matrix was constructed using the Eq. (2). In the following step, the positive and negative ideal solutions considering the three criteria and the rating scale (from 0 to 5) were determined using Eqs. (3) and (4) and the positive and negative ideal separation measures, S_i^* and S_i^- were calculated using Eqs. (5) and (6) respectively. These three decision makers used the defined variables to assess the importance of criteria and evaluate the ratings of candidates with respect to each criterion. The computational procedure of the proposed method and the closeness coefficient of each firm to the ideal solution calculated according to Eq. (7). Finally, even though both results are within the 80%-100% range, and supplier evaluation is therefore highly recommended in both cases, they cannot be properly compared because the firms belong to different material groups and therefore have different expected ideal solutions. Firm A and Firm B belong to the material groups “PCBA” and “PCB” respectively. It can be perceived that sustainable criteria play an important role in sustainable supplier evaluation. The last scenarios demonstrate the applicability and adaptability of our proposed model in the sustainable supplier evaluation process. Hence, a different definition of the ideal alternative, in terms of sustainability, would lead to changes in the supplier evaluation ranking.

6. DISCUSSION AND CONCLUSIONS

With a view to transfer the knowledge to future generations, firms should describe the process in depth and update it accordingly. Therefore, new employees or decision makers can be trained and they can enhance the process standardization. One of the issues we faced during the audit at the Firm B is the language communication barrier found between the end customer’s specification in German language, the tier one translation in Slovakian and the tier two translation

in Chinese. Thus, Firm B (tier two) misunderstood a product's specification because of a translation failure. During the on-site audit, we encouraged the Chinese firm to actively contact its customer for any doubts or questions during the manufacturing or contractual review process. We also recommended writing the specifications as clearly as possible and clarifying this with the second party before processing the customer order. Control plans, failure mode effects analysis (FMEA) and production part approval process (PPAP) reports and processes were not implemented at that time, so the competence transfer involved was more difficult for external providers. Our study highlights the relevance of categorize and differentiate external providers with regards to their material groups' requirements. Thus, requirements concerning PCB manufacturing are different to the ones for injection molding activities.

The supplier evaluation process suggests that the framework is comprehensive and includes the key considerations highlighted in the interviews, thus offering some insight into possible outcomes for decision makers. The framework is coupled with a decision matrix collecting the information defined in the framework, such as the factors and areas for the operationalization of the process. As observed in the multiple case study, while the relevance of environmental factors is greater than economic factors. The social and environmental criteria were not considered in previous supplier evaluation assessments and, at the beginning, they were underestimated by some participants. However, once they understood the meaning of CSR and its positive influence on firm performance, the social and environmental criteria were adopted.

The research presented in this paper has significant theoretical and practical implications in the supply chain in general and procurement management in particular. Although past literature reviews provide valuable results, they were based upon the assessment of supplier evaluation decisions and did not consider the TBL model in combination with other criteria based on strategic or resource position viewpoints, like Gualandris, Klassen, Vachon and Kalchschmidt (2015). They proposed a sustainable evaluation and verification (SEV) model with three interrelated dimensions: inclusivity, scope, and disclosure. Unlike Winter and Lasch (2016), who stated that the sustainability criteria are less important in supplier evaluation than other criteria, we strongly believe that the relevance of social and environmental criteria should be assigned depending on each case study and can be even more relevant than the rest of criteria. Additionally, they did not consider criteria like green energy and energy management, which are highly relevant for environmental responsibility.

The supplier evaluation and selection problem has been studied extensively in the literature. However, this paper aims to contribute to the study of the sustainable supplier evaluation literature on supply chain management through the graphical representation of why and how supplier evaluations are made. The proposed framework was successful in the evaluation of the most suitable green external provider and helping decision makers to analyze the suppliers who did not fit with the firm's policy.

The sustainable supplier evaluation framework presented is intended to address the trends identified in the literature by covering relevant factors considered in supplier evaluation decisions. The objective is to provide a graphical representation of relevant dimensions which need to be studied when examining external provider evaluation decisions. One of the article's main contributions is the integration of the framework into real-life situations. The consistency of the proposed methodology is confirmed based on two case studies of electronics firms. The carbon emissions reduction is particularly important to bring a more sustainable living environment especially in industrial countries like China. This is supported by Yin, Li, Dong, and Xing (2017) in China and we observed these regulations in the audit at the Firm B in Shenzhen. Government regulations like water restrictions play an important role. Whereas social conditions are also relevant to guarantee the sustainability, they forgot to consider them in their research.

This framework not only includes relevant factors to be considered, but also provides a structure to investigate these factors and design a practical decision matrix with a pairwise comparison methodology for the practical operationalization of the framework. In contrast to the approach proposed by Sevkli et al. (2007), we have developed a framework including sustainability criteria for practitioners and academics to deepen their knowledge in the supplier evaluation field. Results reviewed in the multiple case study support the idea that green supplier evaluation in manufacturing can be effectively addressed with the proposed framework. Additionally, it takes into account the need to determine the weightings of decision makers, as seen in the case studies and comprehensively and understandably document the completed supplier evaluation process through the project sheet and a project report. Further testing of the tool involving the parameters defined in the designed framework are addressed during its operationalization.

In contrast to the research works of Kumar, Agarwal, and Sharma (2016); Kumar, Singh and Vaish (2017); and Hashim, Nazam, Yao, Baig, Abrar and Zia-ur-Rehman (2017) who understood the sustainability concept on supply chain in terms of environmental considerations, our study extends this concept by additionally assessing social criteria on supplier evaluations. This study provides a long-term framework for actions in many policy areas and it aims to increase certainty for investment and innovation and ensure that all relevant policies take account of resource efficiency in a balanced manner. Identifying best practices for integrating corporate social responsibility involves the evaluation of external providers' certification according to the ISO 9001, ISO 14001, ISO 50001 and ISO 45001 standards. Accepting the firm's code of conduct and monitoring it throughout the

whole supply chain phase are relevant factors to be considered in order to ensure procurement sustainability.

The perfect integration of the framework within the proposed tool can be used as a guideline to provide managers, practitioners and academics with a practical solution to make external provider evaluation decisions in a more structured and consistent manner. As observed in the multiple case studies, a better understanding of the lessons learned and improvement potentials should be considered for every future decision, especially by setting a goal which is consistent with the relevance and weighting of the clusters. Hence, practitioners can learn from past failures by adapting future requirements and continuously updating the proposed framework and tool. Therefore, it should be perceived as a support tool for the sustainable evaluation of external providers. The framework will involve a two-stage decision process: (1) the sourcing decision and (2) the managerial actions required to implement the decision.

Notwithstanding the above findings and contributions, this study faced a number of limitations and so do its outcomes. Firstly, a potential limitation of this study stems from the fact that our in-depth analysis focused exclusively on two case studies. As a consequence, the comparison with other case studies was not evaluated. Secondly, the integration of the TBL methodology into our framework had not been evaluated in the past, which means more evaluations would be required. However, our findings seem to provide a valuable understanding of the current situation in this research field. The present study equally suggests several future research strands which may encourage more intensive studies in this important area.

In our opinion, this article can prove useful for researchers and decision makers, since new trends are emerging in both areas that will probably lead to future research and implementation in firms. Hopefully, the present paper will give rise to a new approach to studying sustainable supplier evaluation practices. It must be added that our results provide practical guidelines to adopt a sourcing strategy based on the relevance of various determinants for the firm. There is clearly still plenty of room for growth and improvement in the sustainable supplier evaluation literature. Another chance for future researchers is empirically validating other case studies within the proposed theoretical framework.

Admittedly, the research topics listed below have already been investigated. Nevertheless, it is our conviction that a need exists to continue updating what is known about sustainable supplier evaluation decision. What considerations are borne in mind during the sustainable procurement decision process? To what extent does the right supplier evaluation have an impact on firms' operational performance? These and other similar questions should be asked for improving supplier evaluation practices from a sustainable viewpoint.

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